(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 May 2002 (23.05.2002)

PCT

(10) International Publication Number
WO 02/40700 A2

(51) International Patent Classification[7]: C12Q

(21) International Application Number: PCT/US01/45003

(22) International Filing Date: 15 November 2001 (15.11.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/714,692 16 November 2000 (16.11.2000) US

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(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 02/40700 A2

(54) Title: CORTICOTROPIN RELEASING FACTOR RECEPTOR 2 DEFICIENT MICE AND USES THEREOF

(57) Abstract: The present invention provides transgenic mice deficient in corticotropin releasing factor receptor 2 (CRFR2). Mice deficient for CRFR1 exhibit decreased anxiety-like behavior and a decreased stress response. In contrast, CRFR2 null mutant mice are hypersensitive to stress and display increased anxiety-like behavior. These mice are useful for the study of anxiety, depression, and the physiology of the HPA axis. CRFR2 null mutant mice also exhibit increased angiogenesis in all tissues examined. Thus, CRFR2 antagonists may be used to stimulate angiogenesis for the treatment of various conditions. In contrast, CRFR2 agonists may be used to inhibit angiogenesis. A combination of urocortin and bFGF was observed to stimulate rapid hair growth.

CORTICOTROPIN RELEASING FACTOR RECEPTOR 2 DEFICIENT MICE AND USES THEREOF

BACKGROUND OF THE INVENTION

Federal Funding Legend

This invention was produced in part using funds from the Federal government under grant no. NIH DK-26741 and NRSA fellowships DK09841 and DK09551. Accordingly, the Federal government has certain rights in this invention.

Field of the Invention

The present invention relates generally to the fields of neurobiology, endocrinology, and psychiatry. More specifically, the present invention relates to the study of anxiety and to mice deficient for corticotropin releasing factor receptor 2.

Description of the Related Art

Corticotropin releasing factor (CRF) is a critical coordinator of the hypothalamic-pituitary-adrenal (HPA) axis. In response to stress, corticotropin releasing factor released from the paraventricular nucleus of the hypothalamus (PVN) activates corticotropin releasing factor receptors on anterior pituitary corticotropes, resulting in release of adrenocorticotropic hormone (ACTH) into the bloodstream. ACTH in turn activates ACTH

receptors in the adrenal cortex to increase synthesis and release of glucocorticoids (1).

The receptors for CRF, CRFR1 and CRFR2 are localized throughout the CNS and periphery. While CRF has a higher affinity for CRFR1 than for CRFR2, urocortin (UCN), a CRF-related peptide, is thought to be the endogenous ligand for CRFR2 since it binds with almost 40-fold higher affinity than does CRF (2). CRFR1 and CRFR2 share approximately 71% amino acid sequence similarity and are distinct in their localization within the brain and peripheral tissues (3-6). CRFR1 is expressed mainly in the pituitary gland, cortex, cerebellum, hindbrain, and olfactory bulb, whereas CRFR2 is found in the lateral septum, ventral medial hypothalamus (VMH), choroid plexus, and many peripheral sites (3, 7).

Mice deficient for CRFR1 have decreased HPA axis hormone levels, an impaired stress response, and decreased anxiety-like behavior (8, 9). These results coincide with those obtained using CRFR1 specific antagonists *in vivo* (10-12). In contrast, CRFR2 specific antagonists are not currently available, and since its cloning in 1995, little has been elucidated regarding the physiological function of CRFR2. UCN may be the endogenous ligand for CRFR2 and has been shown to be a modulator of feeding when administered centrally (13). Since CRFR2 is localized to the ventral medial hypothalamus, a central site of food intake regulation and satiety, it is possible that urocortin actions on these receptors may affect feeding. Further, peripheral administration of urocortin results in hypotension (2, 14) which may be the result of action at CRFR2 found in vascular endothelial cells (3, 7). Therefore, in order to discern the developmental and physiological roles of CRFR2, CRFR2 null mutant mice were generated and analyzed.

The prior art is deficient in the lack of mice deficient for corticotropin releasing factor receptor 2. The present invention fulfills this longstanding need and desire in the art.

SUMMARY OF THE INVENTION

CRFR2 deficient mice exhibit increased anxiety-like behavior and a hypersensitive HPA axis in response to stress. CRFR1 and CRFR2 null mutant mice provide valuable models of anxiety and depression and may further help delineate the molecular mechanisms underlying these diseases. Study of the corticotropin releasing factor signaling pathway and its role in the management of anxiety and depression may provide the necessary clues required for the effective treatment of these diseases.

Thus, the present invention is directed to a non-natural transgenic mouse with a disruption in at least one allele of the corticotropin releasing factor receptor 2 (CRFR2) such that said mouse does not express corticotropin releasing factor receptor 2 protein from said allele. Preferably, the DNA sequences for exons 10, 11, and 12 of said corticotropin releasing factor receptor 2 allele have been deleted. The transgenic mouse may have these DNA sequences replaced with a neomycin resistance gene cassette. The transgenic mouse may be either heterozygous or homozygous for this replacement. Also included in an embodiment of the present invention are the progeny of a mating between a mouse of the present invention and a mouse of another strain.

Another embodiment of the present invention is the application of a CRFR2 deficient mouse to the study of anxiety or

depression and to test the effects of various compounds on anxiety or depression. For example, a method is provided of screening a compound for anxiety modulating activity, comprising the steps of: a) administering said compound to the transgenic mouse of the present invention; b) testing said mouse for anxiety-related behavior; and c) comparing anxiety-like behavior of said mouse with anxiety-like behavior in a second transgenic mouse of the present invention to which said compound was not administered. In addition, a method of screening a compound for depression-modulating activity is provided, comprising the steps of: a) administering said compound to the transgenic mouse of the present invention; b) testing said mouse for depression-like behavior; and c) comparing depression-like behavior of said mouse with depression-like behavior in a second transgenic mouse of the present invention to which said compound was not administered.

Yet another embodiment of the present involves the use of a CRFR2 deficient mouse in a similar procedure to screen for compounds which affect blood pressure or angiogenesis.

A further embodiment of the current invention is the application of the CRFR2 deficient mice to the study of the physiology of the HPA axis, e.g., a method of screening a compound for effects on the response of the hypothalamic-pituitary-adrenal axis to stress, comprising the steps of: a) administering said compound to a transgenic mouse of the present invention; b) placing said mouse in a stress-inducing situation; c) monitoring plasma levels of corticosterone and adrenocorticotropic hormone in said mouse; and d) comparing said levels to those in a transgenic mouse of the present invention not placed in said stress-inducing situation.

In yet another embodiment of the current invention, the mice can be used to study the effects of a compound on the response of the HPA axis to stress by monitoring plasma levels of corticosterone and ACTH.

Yet another embodiment of the current invention relates to the use of the mice in the study the effect of corticotropin releasing factor receptor 2 on other proteins such as corticotropin releasing factor and urocortin.

Yet another embodiment of the current invention relates to the use of the mice in the study the effect of corticotropin releasing factor receptor 2 on other proteins such as corticotropin releasing factor and urocortin.

A further embodiment of the current invention is the use of the CRFR2 deficient mice to examine CRFR1 responses unhindered by the presence of CRFR2.

Examination of the CRFR2 null mutant mice reveals that the loss of the CRFR2 gene results in increased vascularization in all tissues examined. Thus, another embodiment of the instant invention is the application of the CRFR2 null mutant mice to the study of molecular mechanisms of angiogenic regulation.

In another embodiment of the instant invention, angiogenesis may be stimulated in a target tissue by administering a CRFR2 antagonist to the tissue. One example of such an antagonist is an antisense nucleotide directed against the CRFR2 gene. Heart, brain, pituitary, gonad, kidney, adipose, and gastrointestinal tract are among the tissues in which such a response may be attained. This stimulation of angiogenesis may prove useful in treating infarctions, strokes, and injuries.

In yet another embodiment of the instant invention, angiogenesis may be inhibited in a target tissue by administering a CRFR2 agonist such as urocortin or CRF. CRFR2 agonist-induced inhibition of angiogenesis may be used in the treatment of cancer and diabetic retinopathy.

A further embodiment of the instant invention is directed to a method of stimulating hair growth by implanting urocortin and bFGF under the area of skin on which hair growth is desired or contacting urocortin with the skin in a topical composition.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the matter in which the above-recited features, advantages and objects of the invention, as well as others which will become clear, are attained and can be understood in detail, more particular descriptions of the invention briefly summarized above may be had by reference to certain embodiments thereof which are illustrated in the appended drawings. These drawings form a part of the specification. It is to be noted, however, that the appended drawings illustrate preferred embodiments of the invention and therefore are not to be considered limiting in their scope.

Figures 1A-1E show the procedure used for the generation of CRFR2-Deficient Mice.

Figure 1A: Genomic organization of the CRFR2 gene showing the deletion of exons 10, 11, and 12 which code for half of transmembrane domain five through the end of transmembrane

domain seven. The targeting construct utilized for homologous recombination is also shown

Figure 1B: The disrupted allele was detected by Southern Blot analysis of tail DNA isolated from wild type (+/+), heterozygote (+/-), and null mutant (-/-) mice.

Figure 1C: Autoradiographic binding of ^{125}I-Sauvagine in CRFR2 control (top) and mutant (bottom) mice. Note, no CRFR2 binding in the lateral septum of CRFR2 null mutant mice, while the CRFR1 cortical binding is similar to that of the control mouse.

Figure 1D: Hematoxylin and eosin (H&E) staining of the adrenal gland. Note no difference in adrenal gland size (upper panels) at 10X magnification or structure (lower panels) at 20X magnification, C, cortex; M, medulla; ZG, zona glomerulosa; ZF, zona fasciculata; ZR, zona reticularis; n=8.

Figure 1E: H&E staining of the pituitary glands which were mounted on liver for tissue sectioning (upper panels) at 4X magnification, n=8. Pituitary corticotropes were identified with anti-ACTH antibodies (20) (lower panels) at 10X magnification, n=5. P, posterior lobe; I, intermediate lobe; A, anterior lobe. No gross anatomical differences were observed for the pituitary gland or for the corticotrope localization or expression levels of ACTH.

Figures 2A-2D show the hypersensitivity of HPA axis to stress in mutant animals. *= significantly different from wild type controls at same time point, $p < 0.01$ by Scheffe post-hoc test. Plasma obtained by unanesthetized retro-orbital eyebleeds.

Figure 2A: Pre-stress ACTH plasma levels at 7:00 AM, n=16.

Figure 2B: Basal corticosterone plasma levels for 7:00 AM and 5:00 PM, n=7.

Figure 2C: Time course of restraint stress effects on ACTH.

Figure 2D: Corticosterone plasma levels (7:00 AM) are significantly different from wild type control at same time point, n=7.

Figures 3A-3B show the effect of 24 hours of food deprivation on food intake in wild type and mutant littermate mice.

Figure 3A: Food consumption of mutant mice (n=7) basal and following a 24 hr food deprivation period as compared to wild type litter mates (n=10), $p < 0.001$ by Scheffe post-hoc test.

Figure 3B: Weight of wild type and mutant mice, basal (open bars) and following 24 hrs of refeeding (black bars) following the food deprivation period. Note that there are no differences between groups in basal or refed body weights.

Figures 4A-4D demonstrate the increased anxiety-like behavior of mutant animals in the elevated plus maze, (control n=7, mutant n=7; mean ±SEM).

Figure 4A: Percentage of time spent in the open arms (**, $p<0.005$) and number of visits to the open arms (*, $p<0.02$) were significantly less for the mutant mice than for the wild type controls.

Figure 4B: Locomotor activity was not different between control and mutant animals as measured by total closed arm entries ($p=0.64$) and total arm entries ($p=0.38$).

Figure 4C: No differences were found in anxiety-like behavior measured in the light/dark box experiment for time spent in the light portion of the box.

Figure 4D: No differences were found in anxiety-like behavior measured in the light/dark box experiment for the number of transitions between the light and dark portions.

Figures 5A-5E show the increased levels of urocortin and CRF mRNA in the mutant brains. For 4B to 4E, n=3, ±SEM, *, $p < .05$; ** $p < .01$; ***, $p < .005$.

Figure 5A: Silver grains resulting from *in situ* hybridization (23) for urocortin mRNA in the rostral EW (upper) at 20X magnification and CRF mRNA in cAmyg (middle) and paraventricular nucleus (lower) at 10X magnification.

Figure 5B: Semi-quantitative analysis of silver grains was used to determine cell numbers expressing urocortin mRNA in the rostral EW.

Figure 5C: Average optical density of urocortin mRNA per cell.

Figure 5D: Optical density of CRF mRNA in the cAmyg.

Figure 5E: Optical density of CRF mRNA in the paraventricular nucleus.

Figure 6 shows cardiovascular responses to intravenous infusion of 1.0 µg urocortin in wild type (n = 5) and mutant mice (n = 3). Note the remarkable muted response of mutant mice to the urocortin injection. *** $p < 0.005$.

Figures 7A-7F show tissues from adult CRFR2 control (**Figures 7A, 7C and 7E**) and CRFR2 null mutant (**Figures 7B, 7D and 7F**) mice immunostained with anti-PECAM antibodies. These studies showed an increase in vessel number and size in the anterior pituitary (**Figure 7B**), white adipose tissue (**Figure 7D**) and dorsal brain surface (**Figure 7F**) of CRFR2 null mutant mice as compared

to the anterior pituitary (**Figure 7A**), white adipose tissue (**Figure 7C**) and dorsal brain surface (**Figure 7E**) of control mice.

Figures 8A-8B show immunostained tissues from embryonic day 11 CRFR2 null mutant and control mice. **Figure 8A** shows tissues from the head of CRFR2 null mutant (right) and control (left) mice. **Figure 8B** shows tissues from the front paws of CRFR2 null mutant (right) and control (left) mice. No difference in vessel number and size was observed in either the head or front paws.

Figures 9A-9C show microfil perfused tissues from adult CRFR2 null mutant (right, **Figure 9A, Figure 9B** and **Figure 9C**) and control mice (left, **Figure 9A, Figure 9B** and **Figure 9C**). CRFR2 null mutant mice show increased vessel number in the dorsal brain surface (**Figure 9A**), large intestine (**Figure 9B**) and heart (**Figure 9C**).

Figures 10A-10F show microfil perfused tissues from adult CRFR2 null mutant (**Figure 10B, Figure 10D** and **Figure 10F**) and control mice (**Figure 10A, Figure 10C** and **Figure 10E**). The arrows indicate the primary arteries for the kidney (**Figures 10A** and **10B**), adrenal gland (**Figures 10C** and **10D**) and testis (**Figures 10E** and **10F**).

Figures 11A-11D show microfil perfused tissues from 3 week old CRFR2 null mutant (**Figure 11B** and **Figure 11D**) and control mice (**Figure 11A** and **Figure 11C**). Mutant mice exhibit an increase in the number of blood vessels in the small intestine (**Figures 11B** vs. **11A**) and stomach (**Figures 11D** vs. **11C**).

Figure 12 shows a western blot demonstrating increased VEGF expression in white (WAT) and brown (BAT) adipose tissue from CRFR2 null mutant mice.

Figure 13 shows that surgical implantation of a gel foam sponge impregnated with urocortin and bFGF stimulated hair growth in the area directly over the sponge implant. The mouse on the right received a sponge containing bFGF only. The mouse on the left was implanted with a sponge impregnated with both urocortin and bFGF.

DETAILED DESCRIPTION OF THE INVENTION

In accordance with the present invention there may be employed conventional molecular biology, microbiology, and recombinant DNA techniques within the skill of the art. Such techniques are explained fully in the literature. See, e.g., Maniatis, Fritsch & Sambrook, "Molecular Cloning: A Laboratory Manual (1982); "DNA Cloning: A Practical Approach," Volumes I and II (D.N. Glover ed. 1985); "Oligonucleotide Synthesis" (M.J. Gait ed. 1984); "Nucleic Acid Hybridization" [B. D. Hames & S.J. Higgins Eds. (1985)]; "Transcription and Translation" [B. D. Hames & S.J. Higgins eds. (1984)]; "Animal Cell Culture" [R. I. Freshney, ed. (1986)]; "Immobilized Cells And Enzymes" [IRL Press, (1986)]; B. Perbal, "A Practical Guide To Molecular Cloning" (1984).

Therefore, if appearing herein, the following terms shall have the definitions set out below.

As used herein, the term "cDNA" shall refer to the DNA copy of the mRNA transcript of a gene.

As used herein the term "screening a library" shall refer to the process of using a labeled probe to check whether, under the appropriate conditions, there is a sequence complementary to the

probe present in a particular DNA library. In addition, "screening a library" could be performed by PCR.

As used herein, the term "PCR" refers to the polymerase chain reaction that is the subject of U.S. Patent Nos. 4,683,195 and 4,683,202 to Mullis, as well as other improvements now known in the art.

The amino acids described herein are preferred to be in the "L" isomeric form. However, residues in the "D" isomeric form can be substituted for any L-amino acid residue, as long as the desired functional property of immunoglobulin-binding is retained by the polypeptide. NH_2 refers to the free amino group present at the amino terminus of a polypeptide. COOH refers to the free carboxy group present at the carboxy terminus of a polypeptide. In keeping with standard polypeptide nomenclature, *J Biol. Chem.*, 243:3552-59 (1969), abbreviations for amino acid residues are known in the art.

It should be noted that all amino-acid residue sequences are represented herein by formulae whose left and right orientation is in the conventional direction of amino-terminus to carboxy-terminus. Furthermore, it should be noted that a dash at the beginning or end of an amino acid residue sequence indicates a peptide bond to a further sequence of one or more amino-acid residues.

A "replicon" is any genetic element (e.g., plasmid, chromosome, virus) that functions as an autonomous unit of DNA replication *in vivo*; i.e., capable of replication under its own control.

A "vector" is a replicon, such as plasmid, phage or cosmid, to which another DNA segment may be attached so as to bring about the replication of the attached segment.

A "DNA molecule" refers to the polymeric form of deoxyribonucleotides (adenine, guanine, thymine, or cytosine) in its either single stranded form, or a double-stranded helix. This term refers only to the primary and secondary structure of the molecule, and does not limit it to any particular tertiary forms. Thus, this term includes double-stranded DNA found, *inter alia*, in linear DNA molecules (e.g., restriction fragments), viruses, plasmids, and chromosomes. In discussing the structure herein according to the normal convention of giving only the sequence in the 5' to 3' direction along the nontranscribed strand of DNA (i.e., the strand having a sequence homologous to the mRNA).

An "origin of replication" refers to those DNA sequences that participate in DNA synthesis.

A DNA "coding sequence" is a double-stranded DNA sequence which is transcribed and translated into a polypeptide *in vivo* when placed under the control of appropriate regulatory sequences. The boundaries of the coding sequence are determined by a start codon at the 5' (amino) terminus and a translation stop codon at the 3' (carboxyl) terminus. A coding sequence can include, but is not limited to, prokaryotic sequences, cDNA from eukaryotic mRNA, genomic DNA sequences from eukaryotic (e.g., mammalian) DNA, and even synthetic DNA sequences. A polyadenylation signal and transcription termination sequence will usually be located 3' to the coding sequence.

Transcriptional and translational control sequences are DNA regulatory sequences, such as promoters, enhancers, polyadenylation signals, terminators, and the like, that provide for the expression of a coding sequence in a host cell.

A "promoter sequence" is a DNA regulatory region capable of binding RNA polymerase in a cell and initiating transcription of a downstream (3' direction) coding sequence. For purposes of defining the present invention, the promoter sequence is bounded at its 3' terminus by the transcription initiation site and extends upstream (5' direction) to include the minimum number of bases or elements necessary to initiate transcription at levels detectable above background. Within the promoter sequence will be found a transcription initiation site, as well as protein binding domains (consensus sequences) responsible for the binding of RNA polymerase. Eukaryotic promoters often, but not always, contain "TATA" boxes and "CAT" boxes. Prokaryotic promoters contain Shine-Dalgarno sequences in addition to the -10 and -35 consensus sequences.

An "expression control sequence" is a DNA sequence that controls and regulates the transcription and translation of another DNA sequence. A coding sequence is "under the control" of transcriptional and translational control sequences in a cell when RNA polymerase transcribes the coding sequence into mRNA, which is then translated into the protein encoded by the coding sequence.

A "signal sequence" can be included near the coding sequence. This sequence encodes a signal peptide, N-terminal to the polypeptide, that communicates to the host cell to direct the polypeptide to the cell surface or secrete the polypeptide into the media, and this signal peptide is clipped off by the host cell before the protein leaves the cell. Signal sequences can be found associated with a variety of proteins native to prokaryotes and eukaryotes.

The term "oligonucleotide", as used herein in referring to the probe of the present invention, is defined as a molecule comprised of two or more ribonucleotides, preferably more than three. Its exact size will depend upon many factors which, in turn, depend upon the ultimate function and use of the oligonucleotide.

The term "primer" as used herein refers to an oligonucleotide, whether occurring naturally as in a purified restriction digest or produced synthetically, which is capable of acting as a point of initiation of synthesis when placed under conditions in which synthesis of a primer extension product, which is complementary to a nucleic acid strand, is induced, i.e., in the presence of nucleotides and an inducing agent such as a DNA polymerase and at a suitable temperature and pH. The primer may be either single-stranded or double-stranded and must be sufficiently long to prime the synthesis of the desired extension product in the presence of the inducing agent. The exact length of the primer will depend upon many factors, including temperature, source of primer and use the method. For example, for diagnostic applications, depending on the complexity of the target sequence, the oligonucleotide primer typically contains 15-25 or more nucleotides, although it may contain fewer nucleotides.

The primers herein are selected to be "substantially" complementary to different strands of a particular target DNA sequence. This means that the primers must be sufficiently complementary to hybridize with their respective strands. Therefore, the primer sequence need not reflect the exact sequence of the template. For example, a non-complementary nucleotide fragment may be attached to the 5' end of the primer, with the remainder of the primer sequence being complementary to the

strand. Alternatively, non-complementary bases or longer sequences can be interspersed into the primer, provided that the primer sequence has sufficient complementary with the sequence or hybridize therewith and thereby form the template for the synthesis of the extension product.

As used herein, the terms "restriction endonucleases" and "restriction enzymes" refer to enzymes, each of which cut double-stranded DNA at or near a specific nucleotide sequence.

A cell has been "transformed" by exogenous or heterologous DNA when such DNA has been introduced inside the cell. The transforming DNA may or may not be integrated (covalently linked) into the genome of the cell. In prokaryotes, yeast, and mammalian cells for example, the transforming DNA may be maintained on an episomal element such as a plasmid. With respect to eukaryotic cells, a stably transformed cell is one in which the transforming DNA has become integrated into a chromosome so that it is inherited by daughter cells through chromosome replication. This stability is demonstrated by the ability of the eukaryotic cell to establish cell lines or clones comprised of a population of daughter cells containing the transforming DNA. A "clone" is a population of cells derived from a single cell or ancestor by mitosis. A "cell line" is a clone of a primary cell that is capable of stable growth *in vitro* for many generations.

In general, expression vectors containing promoter sequences which facilitate the efficient transcription of the inserted DNA fragment are used in connection with the host. The expression vector typically contains an origin of replication, promoter(s), terminator(s), as well as specific genes which are capable of providing phenotypic selection in transformed cells. The

transformed hosts can be fermented and cultured according to means known in the art to achieve optimal cell growth.

Methods which are well known to those skilled in the art can be used to construct expression vectors containing appropriate transcriptional and translational control signals. See for example, the techniques described in Sambrook et al., 1989, *Molecular Cloning: A Laboratory Manual* (2nd Ed.), Cold Spring Harbor Press, N.Y. A gene and its transcription control sequences are defined as being "operably linked" if the transcription control sequences effectively control the transcription of the gene. Vectors of the invention include, but are not limited to, plasmid vectors and viral vectors.

The current invention is directed to mice deficient in CRFR2, which were generated to discern the developmental and physiological roles of CRFR2 in anxiety and HPA axis circuitry. This has been done by deleting exons 10, 11, and 12 of corticotropin releasing factor receptor 2. In the present invention, these sequences have been replaced with a neomycin resistance gene cassette. The mice may be either heterozygous of homozygous for the CRFR2 deficiency and may be crossed with mice of another strain.

The present invention is also directed to the application of the CRFR2 deficient mice in the study of anxiety and depression, including methods of testing a compound for anxiety or depression modulating activity. Compounds which affect blood pressure and angiogenesis can also be screened using the CRFR2 mice.

The current invention is also directed to use of the CRFR2 deficient mice in the study of the molecular physiology of the hypothalamic-pituitary-adrenal (HPA) axis. The mice can be used to

test the effects of a compound on the response of the HPA axis to stress.

The current invention is also directed to the use of the transgenic mice to study the molecular functions of corticotropin releasing factor receptor 2 on corticotropin releasing factor, corticotropin releasing factor receptor 1, urocortin, and other CRF and urocortin receptors.

In addition, the present invention can be used to study the responses and activities of CRFR1 in a CRFR2 negative environment. In this manner, CRFR1 responses can be studied unhindered by CRFR2 modulation.

The instant invention is also directed to the use of the CRFR2 null mutant mice to the molecular regulation of angiogenesis.

The instant invention is also directed to a method of stimulating increased angiogenesis by administering a CRFR2 antagonist to a target tissue. One manner in which this may achieved is through the use of an antisense nucleotide directed against CRFR2. Heart, brain, pituitary, gonad, kidney, adipose, and gastrointestinal tract are among the tissues in which such a response may be attained. The instant invention will prove useful in stimulating increased angiogenesis following infarction, stroke, and injury.

The instant invention is also directed to a method of inhibiting angiogenesis by administering a CRFR2 agonist to a target tissue such as heart, brain, pituitary, gonad, kidney, adipose, or gastrointestinal tract tissues. CRFR2 agonists include urocortin and CRF. Cancer and diabetic retinopathy are examples of conditions which may be responsive to a CRFR2 agonist induced inhibition of angiogenesis.

The instant invention is directed to a method of stimulating hair growth comprising the step: contacting urocortin with a region of skin on which hair growth is desired. In one aspect, the urocortin may be implanted under the skin. Although urocortin may be useful alone, bFGF may also be administered to the skin before urocortin, after urocortin or simultaneously with urocortin. Urocortin may also be contained in a composition with bFGF.

The following examples are given for the purpose of illustrating various embodiments of the invention and are not meant to limit the present invention in any fashion.

EXAMPLE 1

Generation of the CRFR2 Deficient Mice

For the construction of CRFR2 null mutant mice, a genomic clone DNA containing the *CRFR2* locus was isolated from a mouse strain 129 genomic DNA library. From this clone, a targeting vector was constructed in which the exons 10, 11, and 12 of the *CRFR2* gene encoding the beginning of the fifth transmembrane domain through the end of the seventh transmembrane domain were replaced with a neomycin resistance gene cassette (Figure 1A). The resulting plasmid DNA was linearized with Not I and electroporated in to J1 embryonic stem (ES) cells as previously described (8). After selection in 0.2 mg/ml G418 (active form) for 7-9 days, neomycin resistant clones were individually selected and screened for the presence of the disrupted CRFR2 allele by Southern blot analysis.

Positive ES clones were injected into C57 BL/6 blastocysts to generate chimeric mice. Chimeric males were crossed to C57BL/6 females and germ-line transmission of the disrupted allele was determined by Southern analysis of tail DNA collected from F1 pups displaying agouti coat color (Fig. 1B).

EXAMPLE 2

Analysis of CRFR1 and CRFR2 expression in CRFR2 Deficient Mice

To determine if the targeted deletion resulted in a null mutation of the CRFR2 gene, receptor autoradiography was performed on brain sections from wild type control and mutant animals.

Slides containing 20 μm sectioned brain tissue were thawed at room temperature and washed twice for 10 min. in 50 mM Tris buffer (pH 7.4) at room temperature. Sections were then incubated in buffer containing 50 mM Tris (pH 7.4), ^{125}I-Sauvagine, 10 mM $MgCl_2$, 0.1% BSA, and 0.05% bacitracin for 60 min. at room temperature. Nonspecific binding was defined in adjacent sections that were exposed to both ^{125}I-Sauvagine and 1 μm cold sauvagine. After the incubation period, slides were washed in a 50 mM Tris buffer plus 0.01% Triton X-100 at 4 C twice for 5 min. each. Slides were rapidly dipped in deionized water, dried and apposed to film for 3 days.

In the mutant mice, no binding in brain regions specific to CRFR2 (lateral septum) was detected, yet binding to CRFR1 in the cortex was retained (Figure 1C). These results demonstrate that the disruption of the CRFR2 gene resulted in a null mutation in these

mice. Mutant mice were fertile and transmitted the mutant allele in a Mendelian fashion.

EXAMPLE 3

Histological analysis of CRFR2 Deficient Mice

To determine whether the development of the HPA axis was compromised in the CRFR2 deficient mice, the pituitary and adrenal glands of male mice 10-12 week of age were sectioned and stained with hematoxylin and eosin (H&E). Briefly, mice were perfused with 4% paraformaldehyde (PFA). Tissues were removed, postfixed overnight at 4 C, and cryoprotected in 30% sucrose in PBS. Tissues were sectioned at 12 μm thickness and stained with hematoxylin and eosin. The results showed no obvious differences in structure or cell types (Figs. 1D-1E).

In addition, pituitary sections were stained with anti-ACTH antibodies. The pituitaries were sectioned, postfixed in 4% PFA for 5 min., rinsed in PBS, and stained with ACTH antibody as described previously (6). No qualitative differences were noted between wild type and mutant corticotropes (Fig. 1E).

EXAMPLE 4

Determination of corticosterone and ACTH levels in CRFR2 deficient mice

For corticosterone and ACTH analyses, plasma was obtained from individually housed male mice of 10-12 weeks of age.

Samples were collected by retro-orbital eye bleed from unanesthetized animals within 30 sec of disturbance of the cage. Basal AM samples were collected at 7:00 AM. Basal PM samples were collected at 5:00 PM. Corticosterone assay (ICN Biomedicals, Dosta Mesa, CA) used 5 µl plasma and the ACTH assay (Nichols Institute Diagnostics, San Juan Capistrano, CA) used 50 µl plasma as measured in duplicate by radioimmune assay kits. Normal basal levels of ACTH and corticosterone were found in the mutant and control animals (Fig. 2A-2B), consistent with the finding that ACTH levels are unaffected in the brain.

EXAMPLE 5

Effects of stress on the HPA axis response in CRFR2 deficient Mice

In order to examine the HPA axis response to stress, animals were subjected to physical restraint-stress for increasing lengths of time. Blood samples were collected immediately following either 2, 5, or 10 min. of restraint stress in a 50 ml conical tube (plastic conical tube with the bottom removed). Plasma samples were immediately centrifuged and stored at -20C until the assay was conducted.

ACTH levels in the mutant animals were significantly elevated and peaked following only two minutes of restraint stress (Fig. 2C). In contrast, ACTH levels in control animals peaked following ten minutes of restraint. Similarly, corticosterone levels in the mutant animals were significantly elevated following two minutes of restraint, whereas control animal levels increased following five minutes of the stress (Fig. 2D). These results

demonstrated a hypersensitive response of the HPA axis to stress in the mutant mice.

EXAMPLE 6

CRFR2 deficient mice are sensitive to food deprivation

Since CRFR2 is abundant in the VMH and since previous studies had shown an anorectic effect of icv urocortin (13), basal feeding and weight gain were measured in the mutant and wild type litter mates.

Basal feeding was measured in individually housed 12-16 week old male litter mates. Mice and their food pellet were weighed daily at 09:00 hrs. For the food deprivation experiment, control and mutant litter mates were individually housed and their basal food intake and weight was established. Mice were food deprived for 24 hrs beginning at 12:00 hrs, but had water ad libidum. Following the food deprivation period, mice were weighed and given a pre-weighed food pellet. Food pellets were then weighed every two hours until lights off (18:00 hrs). Food pellets and mice were again weighed the following morning. Weight loss during the food deprivation as well as total food consumption and weight gain over the 24 hr period following the food deprivation were recorded.

Basal feeding and weight gain in CRFR2 null mutant (mut) male mice were similar to that of wild type (wt) litter mates (24 hr basal food consumption wt = 4.3 ± 0.24 g, mut = 4.6 ± 0.23 g; body weight wt = 21.7 ± 0.66 g, mut = 21.2 ± 0.50 g; n=10, averages are ± sem).

In order to determine if a stressful stimulus would alter the mutant animals' food intake, control and mutant mice were food deprived for 24 hrs and then refed, following which their food intake and weight changes were measured. Food deprivation results showed a significant decrease in food intake in the mutant mice following 24 hrs of food deprivation (Fig. 3A). Mutant mice consumed 75% of wild type food levels in the 24 hr period following the food deprivation. However, the mutant and wild type body weights were not significantly different following food deprivation or refeeding (Fig. 3B).

EXAMPLE 7

Evaluation of anxiety-like behavior in CRFR2 deficient mice in Elevated Plus Maze

Since CRFR1 mutant mice displayed anxiolytic-like behavior (8), CRFR2 null mutant mice were analyzed in similar tests. Control and mutant animals were evaluated using the elevated plus maze (EPM). Male mice between 22-24 weeks of age were used in this experiment. Littermate wild type mice were used as the controls. Animals were group housed, maintained under regular light/dark conditions (lights on 6:00 AM, lights off 6:00 PM), and handled on alternate days one week prior to testing.

The plus maze apparatus was made of black Plexiglas and had two open arms (30 x 5 cm) and two enclosed arms of the same size with walls 30 cm high. It was elevated 30 cm above the ground. The arms were connected by a central square (5x5 cm) and thus the maze formed a plus sign. A 25 watt lamp placed above the

apparatus provided a 6 lux light level in the open arms. All testing was performed during the light phase of the light-dark cycle. Mice were habituated to the experimental room conditions for 1 hour prior to the behavioral testing and the subjects were individually tested in 5-min sessions.

Each mouse was placed on the center platform facing an open arm to initiate the test session. Behaviors scored were the number of open and closed arm entries and the amount of time spent on the various sections of the maze. Arm entries were defined as an entry of all four paws into the arm. Closed arm entries were taken as an index of locomotor activity in the plus maze. A camera mounted above the apparatus allowed the observation of animal behavior on a video monitor placed in an adjacent room. At the end of the test, the number of entries into and the time spent on the open arms were expressed as a percentage of the total number of arm entries and test duration, respectively. Results are expressed as the mean ± standard error of the mean. Behavioral parameters obtained from the EPM test were analyzed using the Student's t test.

Results showed that CRFR2 null mutant mice spent less time on and entered less frequently the open arms of the plus-maze apparatus than did the wild type controls. A significant effect was found for both percent entries into the open arms [$t\ (12)=2.684$; $p<0.02$] and percent time in the open arms [$t\ (12)=3.524$; $p<0.005$] (Fig. 4A). The increase in anxiety-like behavior was not due to altered locomotor activity, as overall activity in closed arm [$t\ (12)=0.469$; $p=0.64$] and total arm entries [$t\ (12)=0.904$; $p=0.38$] was not different between the two groups (Fig. 4B). These results demonstrate that CRFR2 null mutant mice exhibit markedly increased anxiety-like behavior.

EXAMPLE 8

Evaluation of anxiety-like behavior in CRFR2 deficient mice in a light/dark box

The behavior of CRFR2 null mutant and control mice was also analyzed for anxiety-like behavior in a light/dark box. A rectangular, plexiglass box was divided into two compartments, one painted white (28.5 cm x 27 cm) and one painted black (14.5 cm x 27.0 cm). Light intensity was 8 lux in the black compartment which was covered by a red plexiglass lid and 400 lux in the white compartment. The compartments were connected by an opening (7.5 cm x 7.5 cm) located at floor level in the center of the partition. All testing was done during the dark phase of the cycle, between 19:00 hrs and 21:00 hrs. Each animal was tested for 10 min by being placed in the center of the white area and the number of transitions between the two compartments and the amount of time spent in the white area was recorded. A camera mounted above the apparatus allowed for observation and recording from an adjacent room.

Results from the Light/Dark box demonstrated that CRFR2 null mutant mice spent as much time in the light portion of the box and had as many transitions between the light and dark portions of the box as control mice (Fig. 4C&D). No significant differences were detected between the two groups in this experiment.

EXAMPLE 9

Effect of CRFR2 deficiency on the expression of other genes

As no gross anatomical defects were detected in components of the HPA axis (Figures 1D & 1E), the alterations in stress and behavioral responses in the mutant animals may be due to altered gene expression of other components of the CRF signaling pathway. To investigate this possibility, expression of UCN, CRF, and CRFR1 mRNAs were examined by *in situ* hybridization.

In situ hybridization was performed according to methods described previously (15). Briefly, tissue sections (20 µm) were fixed in 4% paraformaldehyde, rinsed in PBS, immersed in acetic anhydride, dehydrated through a series of graded ethanol, de-lipidated in chloroform, and again dehydrated. Slides were then hybridized with an ^{35}S-labeled riboprobe in a 50% deionized formamide hybridization mix overnight at 55°C in a humidified incubation chamber. Following the incubation, slides were washed in 1X SSC at room temperature for 30 minutes with shaking, treated with 20 µg/ml RNase (Promega) at 37 C for 30 min., rinsed in 1X SSC buffer at room temperature for 30 minutes, washed 3X for 20 minutes at 65 C in 0.1X SSC with shaking, rinsed in 0.1X SSC at room temperature for 30 minutes, dehydrated in a series of graded ethanols, air dried, and apposed to Kodak hyperfilm (Eastman Kodak, Rochester, NY) for three days.

After films were developed, slides were dipped in NTB2 liquid nuclear emulsion (Eastman Kodak; diluted 1:1 with water), exposed for 10 days, photographically processed, counter-stained with hematoxylin, and coverslipped. Slides were analyzed using the image analysis system Image Pro Plus (Media Cybernetics, Silver

Springs, MD). For analysis of the PVN and cAmyg, a circle tool (area=3022 pixels) was used to determine mean optical density for each section such that anatomically atlas matched sections for each animal were compared in the identical region of the PVN and cAmyg. The EW cell bodies expressing urocortin were too diffuse to analyze using standard optical density methods. Therefore, parameters were used such that the computer determined the number of cells within the designated EW expressing a minimum optical density by color and cell size as predetermined to exclude non-positive cells and background silver grains. Each cell determined to be positive by the computer for urocortin mRNA was then also counted for optical density. The average optical density and cell number for each section was then compared.

As illustrated in Figure 5A, urocortin mRNA was significantly increased in the rostral region of the Edinger Westphal (EW) nucleus for both the number of cells expressing (Fig. 5B) as well as in the density of urocortin mRNA per cell (Figure 5C) in the mutant animals. The central nucleus of the amygdala (cAmyg) showed a significant increase in CRF mRNA in the null mutant animals (Figs. 5A & 5D). No significant change in CRF mRNA in the PVN was detected in basal, nonstressed animals (Figure 5A & 5E). The expression patterns or levels of CRFR1 mRNA in the brain or anterior lobe of the pituitary gland did not differ between the mutant and wild type mice (data not shown). These results show that CRFR2 null mutant mice have increased expression levels of CRF mRNA in the cAmyg and urocortin mRNA in the rostral Edinger Westphal nucleus.

EXAMPLE 10

Evaluation of hypotension in response to UCN in CRFR2 null mutant mice

Previous reports have shown hypotension in response to a peripheral injection of urocortin (2). Additionally, CRFR2s have been localized to the vascular endothelial cells (3, 7) and have been hypothesized to be responsible for the vasodilatory action of urocortin. In order to test this hypothesis, CRFR2 null mutant and control mice were injected with urocortin and the alteration in their blood pressure was measured.

The cardiovascular responses to intravenous infusion of urocortin and sodium nitroprusside, a vasodilator, were examined in mice (wild type: n = 5; mutant: n = 3) anesthetized with isofluorine. The arterial catheter for blood pressure recording was fabricated from a sterile PE-10 tubing softened and pulled to an outer diameter of ~0.4 mm. The femoral artery was exposed, and the arterial catheter filled with heparin saline (500 U/ml) was implanted and secured with surgical threads and tissue glue (Vetbond). The catheter was connected to a blood pressure transducer (Statham), and the arterial pressure pulses were displayed on a Gould pen-recorder. A second catheter was then implanted in the external jugular vein for intravenous infusion of drugs. Drug infusion was performed 30 min following completion of the cannulation procedure. The venous catheter was connected to a drug-filled syringe. Infusion was completed within 0.5-1.0 min. Both wild type and mutants received an identical dose of urocortin (0.1 µg in 200 µl of 0.9% saline) and saline (as a control).

The doses used were determined from preliminary experiments with reference to data obtained from corresponding studies in Sprague Dawley rats (2). In order to verify that the lack of cardiovascular response to the urocortin injection in mutants was not attributed to the loss of ability of the mice to vasodilate, the mutant mice also received a second infusion of sodium nitroprusside (0.8 μg in 100 μl of 0.9% saline) following recovery of arterial pressure from the urocortin infusion. The mean arterial pressure (MAP) was determined from the blood pressure tracings.

Intravenous infusion of urocortin (0.1 μg) resulted in a prominent depressor response (-28.3 ± 2.0 mm Hg) in control mice (Fig. 6). The reduction in arterial pressure persisted throughout the recording period (90-120 min). In stark contrast, the mutants showed no measurable responses to urocortin (only 1 mutant mouse examined showed a very small and transient reduction (-3.5 mmHg) in arterial pressure which is likely attributable to the injection pressure itself) (Fig. 6). In order to verify that the peripheral vasculature of the mutants was able to vasodilate in response to another stimulus, sodium nitroprusside (NP), which causes vasodilation as a nitric oxide donor, was administered to mutant mice. A rapid and robust depressor response was consistently observed in response to the sodium nitroprusside injection (-30.0 ± 5.0 mm Hg).

EXAMPLE 11

Summary of effects of CRFR2 deletion on anxiety and stress

The results presented here suggest that the CRFR2 null mutant mice display a stress-sensitive and anxiety-like phenotype. Although basal feeding and weight gain were normal, mutant mice responded to food deprivation by consuming less food following the stress of food deprivation. While this may be an effect of metabolism, it is possible that the stress of food deprivation alters the anxiety state of the animal thus decreasing their appetite. The mutant mice also displayed a rapid HPA response to restraint stress, again suggesting that these animals are more sensitive to stress. The decrease in ACTH levels in the mutants observed following ten minutes of restraint may be the result of a more rapid negative glucocorticoid feedback on the hypothalamus, since the mutant mice showed higher steroid levels earlier than the control mice. Taken together, the feeding and HPA axis results suggest a hypersensitivity to stress in the CRFR2 null mutant mice, although one can not rule out other physiological explanations for either the altered feeding response or the increased rate in which the HPA axis in the mutant mice responds to stress.

The mutant mice also display increased anxiety-like behavior in the EPM. However, these mice show similar levels of anxiety-like behavior in the light/dark box. Although pharmacological sensitivity and specificity has generally been demonstrated across many animal tests of anxiety, task differences are sometimes observed (16, 17). While both are classified as unconditioned exploration tests, the light/dark box measures neophobia in addition to exploration. Performance in the EPM is

determined by exploration of aversive environments (18). Light conditions during testing can also significantly influence the ability to detect anxiolytic or anxiogenic effects in animal tests (16). This profile of results for the CRFR2 null mutant mice demonstrates heightened emotionality related to exploration of aversive environments but not neophobia. Previous reports have shown that mice deficient for neuropeptide Y (NPY) display a similar behavioral phenotype, normal in the light/dark box but anxious in the EPM (19). These NPY mutant mice were classified as being anxious which supported previous findings that an injection of NPY decreased anxiety (20). The results obtained with the CRFR2 null mutant mice demonstrate that the EPM may be a more sensitive task for detecting the anxiety in these mice.

EXAMPLE 12

Possible effects of increased CRF in cAmyg on anxiety

Increased CRF mRNA in the cAmyg may explain the anxiety-like behavior and increased HPA axis sensitivity of the mutant mice, since this nucleus expresses CRFR1 (7) and plays a major role in transduction of stress signals (21). In addition, the septum which contains an abundance of CRFR2 has been shown to modulate the activity of the amygdala (22-24) and lesions of this nucleus result in decreased ACTH secretion following restraint stress (25-28). Therefore, it is possible that during stress CRFR2 in the lateral septum modulates activity of the amygdala, and in the absence of CRFR2, unimpeded amygdala activity may result in a rapid HPA response and increased anxiety-like behavior.

Lesions of the amygdala have been shown to block CRF-induced anxiety (21) as well as hyperemotionality resulting from septal lesions (22). This neural pathway may explain the decreased anxiety-like behavior seen in the CRFR1 deficient mice (8) as well as the increased anxiety-like behavior in the CRFR2 deficient mice. Therefore, the CRFR2 null mutant mouse provides possible evidence for a novel mechanism of receptor modulation in anxiety-like behavior.

EXAMPLE 13

Possible mechanisms for anxiety caused by increased UCN mRNA in the rostral EW

Increased urocortin mRNA in the rostral EW may be a second mechanism leading to increased anxiety-like behavior in the mutant mice, since urocortin has been shown to induce anxiety-like behaviors when injected intravenously (29). The rostral EW projects to many regions in the CNS including the locus coeruleus (LC) (30) and injection of the urocortin-related molecule, CRF, into the locus coeruleus results in an anxiety-like response (31). Thus, increased urocortin mRNA in the rostral EW may activate the locus coeruleus to elevate anxiety-like responses and/or hypersensitivity to stress.

EXAMPLE 14

CRFR2 Null Mice and the sensitivity of the autonomic nervous system

Additional explanations for the increased anxiety-like behavior, such as heightened sensitivity of the autonomic nervous system (32-34), cannot yet be ruled out. Previous studies using antisense oligonucleotides have found conflicting results regarding the role of CRFR2 in anxiety and behavior (35, 36).

Although these reports show an anxiolytic-like effect by injection of CRFR1 antisense oligonucleotides, neither study reported consistent findings regarding injection of the CRFR2 antisense oligonucleotides. While the technique of antisense oligonucleotide injection offers potential promise, it remains under scrutiny since decreased levels of protein cannot be substituted for complete elimination of the target, as is accomplished in a knock-out animal.

EXAMPLE 15

Effect of UCN on vasodilation confirmed

Absence of CRFR2 in the null mutant mice allowed for confirmation of the effect of urocortin on vasodilation. Mutant mice had no response to intravenous urocortin, while wild type animals showed a dramatic decrease in mean arteriole pressure. Injection of nitroprusside resulted in vasodilation in the mutants, thus confirming that the lack of response to urocortin was not due to a physical inability of the mutant vasculature to dilate, but specifically to the absence of CRFR2. These results support the

hypothesis that the effect of urocortin on hypotension (2, 14) occurs via action at CRFR2 in the vascular endothelial cells (3, 7), since the CRFR2 null mutant mice showed no response to urocortin. Although the physiological stimulus under which UCN-induced vasodilation would most likely occur is not currently known, the effect of urocortin on CRFR2 in the vasculature may be an interesting target in drug development for hypertension.

Summary

In summary, these results demonstrate that CRFR2 deficient mice exhibit increased anxiety-like behavior in an elevated plus maze and a hypersensitive HPA axis in response to stress. CRFR1 and CRFR2 null mutant mice provide valuable models of anxiety and depression and may further help delineate the molecular mechanisms underlying these diseases. Study of the CRF signaling pathway and its role in the management of anxiety and depression may provide the necessary clues required for the effective treatment of these diseases.

EXAMPLE 16

Angiogenesis is Stimulated in CRFR2 Null Mutant Mice

The CRFR2 null mutant mice appeared to exhibit an increase in the size and number of blood vessels in various tissues. Since the CRFR2 receptor and its activity have been localized within the endothelial cell layer of blood vessels (3, 7), it was hypothesized that CRFR2 may play a role in regulating angiogenesis. To confirm

that CRFR2 null mutant mice had an increased number of blood vessels of larger size, tissues from control and CRFR2 null mutant mice were immunostained with an antibody against platelet-endothelial cell-adhesion molecule (PECAM), a blood vessel specific marker.

Tissues were obtained from the anterior pituitary, white adipose tissue, and dorsal brain surface of both control and CRFR2 null mutant mice of 3-4 months of age. After the tissues were fixed in 4% paraformaldehyde for two days, the tissues were bleached in Dent's fix (4:1 methanol:DMSO) plus 5% hydrogen peroxide overnight. The tissues were washed 3 times in 1X TBS with 1% Tween-20 for 30 minutes each and blocked overnight with 5% goat serum in dilution buffer (0.5 M NaCl, 0.01 M PBS, 3.0% BSA, and 0.3% Triton X-100) plus 1% DMSO at room temperature. On the following day, a 1:1000 dilution of anti-PECAM antibody (Pel Freeze) was added to the blocking mix, which was then incubated for another 2 days at room temperature. The antibody was removed and the tissues were washed 3 times for 1 hour each with 1X TBS plus 1% Tween-20 and 1% DMSO. Goat anti-RAT HRP secondary antibody was added at a 1:5000 dilution and allowed to incubate overnight at room temperature. The tissues were washed as above and a final wash in 1X TBS alone was performed for 1 hour at room temperature. The peroxidase reaction was carried out in the presence of glucose oxidase-containing (Calbiochem) reaction mix until an orange-brown color developed. The tissues were dehydrated in a graded methanol series and cleared with glycerol.

The results of the anti-PECAM immunostaining are shown in Figures 7A-7F. These experiments confirmed that the absence of the CRFR2 receptor in the null mutant mice results in an increase in

number and size of blood vessels in the anterior pituitary (Figure 7B), white adipose tissue (Figure 7D) and dorsal brain surface (Figure 7F). The same tissues in control mice are shown in Figure 7A-anterior pituitary; Figure 7C - white adipose tissue; and, Figure 7E - dorsal brain surface. Therefore, one of the roles of the CRFR2 receptor in normal mice is to mediate a CRF-induced inhibition of angiogenesis.

EXAMPLE 17

CRFR2 has no effect on angiogenesis in embryonic mice

To determine whether the CRFR2 receptor may be involved in blood vessel formation during embryonic development, anti-PECAM immunostaining experiments were performed on tissue sections from day 11 embryonic mice. Sections of tissues from embryonic mice were prepared and treated in the same manner as the sections from adult mice.

Figures 8A shows anti-PECAM immunostained sections from the heads of CRFR2 null mutant (right) and control (left) mice, while Figure 8B shows immunostained sections from the front paws of CRFR2 null mutant (right) and control (left) mice. No difference in vessel number or size was observed between CRFR2 null mutant mice and control mice in either the head or front paw tissue sections. Thus, CRFR2 appears to be involved in angiogenesis only in fully developed mice.

EXAMPLE 18

Microfil polymer characterization of vascularization in adult mice

To further characterize the hypervascularization of CRFR2 null mutant mice, the vascular tissues of control and mutant mice were perfused with microfil polymer to confirm that an increase in vessel volume had occurred. In preparation for perfusion, a 30 gauge needle was placed in the left ventricle of anesthetized adult or three week old CRFR2 null mutant and control mice. The perfusion was performed with a syringe pump until the perfusate drained freely from a drain vent opened in the right atrium for that purpose. The animals were placed at 4° C overnight to allow the polymer to cure. Tissue sections were dissected from the cured animals and dehydrated through a graded ethanol series starting with 25% ethanol on day one. After bleaching with 6% hydrogen peroxide on day 2, the ethanol series was continued with 50% ethanol followed by 75% ethanol on day 3, 95% ethanol on day 4, and 100% ethanol on day 5. The tissues were then cleared in glycerol prior to analysis. Following removal of the soft tissue, the volumes of the vascular beds of various tissues could be observed.

Figures 9 and 10 show microfil perfused tissues from adult CRFR2 null mutant and control mice. In Figure 9, the tissue from the normal mouse is shown on the left side of each panel while a similar section from a CRFR2 null mutant mouse is shown on the right side. Increased vessel size and number are observed in all tissues from CRFR2 null mutant mice including the dorsal brain surface (Figure 9A), large intestine (Figure 9B) and heart (Figure 9C). In Figures 10, the primary arteries for the kidney (Figures 10A and 10B), adrenal glands (Figure 10C and Figure 10D) and testis

(Figures 10E and 10F) are indicated with arrows. The major vessels of the CRFR2 null mutant (Figure 10B, Figure 10D and Figure 10F) mice are significantly increased in size relative to those of the control mice (Figure 10A, Figure 10C and Figure 10E). These results, combined with the anti-PECAM immunostaining results, confirm that mice deficient for CRFR2 exhibit increased hypervascularization in all tissues observed including the brain, heart, pituitary gland, and gastrointestinal tract. Both the size and number of blood vessel was increased.

Microfil perfused tissues from 3 week old mice are shown in Figures 11A-11D. The CRFR2 null mutant mice exhibit an increase in the number of blood vessels in the small intestine (Figure 11B vs. Figure 11A) and stomach (Figure 11D vs. Figure 11C). These results suggest that hypervascularization first increases the number of blood vessels and the blood vessels increase in size as the mouse ages.

EXAMPLE 19

Analysis of VEGF Expression in CRFR2 null mutant mice

To determine if CRFR2 has an effect on vascular endothelial growth factor (VEGF) expression, tissues from CRFR2 null mutant and control mice were examined by western blot analysis for VEGF content. White (WAT) and brown (BAT) adipose tissues were homogenized in buffer (50 mM TrisHCl, pH 7.4, 1 mM DRR, 2 mM MgCl2, 1 mM EDTA, 0.5 mM PMSF, 5 μg/ml leupeptin, 2 μg aprotinin). 40 μg aliquots of the protein extracts were separated on a 10% SDS-PAGE gel (Novex, San Diego) and transferred to

nitrocellulose membranes. The blots were blocked in 5% nonfat dry milk for 1 hour and washed with 1X TBS plus 0.2% Tween-20 (TBST). The blots were then incubated with a 1:1000 dilution of anti-VEGF antibody for 1 hour, washed twice in TBST for 20 minutes each, and incubated with a 1:10,000 dilution of anti-rabbit HRP for 1 hour. After being washed twice in TBST for 20 minutes each time, the blots were visualized with ECL reagent. A representative blot is shown in Figure 12. Increased VEGF expression was observed in all tissues examined from CRFR2 null mutant mice, indicating a possible interaction between CRFR2 and VEGF production.

EXAMPLE 20

Hair Growth is Stimulated in Urocortin Treated Mice

Small regions area of mice were shaved over of their skin and gel foam sponges impregnated with bFGF and urocortin, various growth factors, and CRF antagonist astressin were surgically implanted under the shaved skin. In the mice implanted with both bFGF and urocortin, substantial hair growth in the area immediately above the implanted sponge was observed after only five days. Little hair growth was observed in the shaved area of mice implanted with sponges containing only growth hormones or astressin. Figure 13 shows the hair growth in a mouse implanted with urocortin and bFGF as compared to a mouse in which only bFGF was implanted. Therefore, urocortin and bFGF stimulate rapid hair growth.

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Any patents or publications mentioned in this specification are indicative of the levels of those skilled in the art to which the invention pertains. These patents and publications are herein incorporated by reference to the same extent as if each individual publication was specifically and individually indicated to be incorporated by reference.

One skilled in the art will readily appreciate that the present invention is well adapted to carry out the objects and obtain the ends and advantages mentioned, as well as those inherent therein. The present examples along with the methods, procedures, treatments, molecules, and specific compounds described herein are presently representative of preferred embodiments, are exemplary, and are not intended as limitations on the scope of the invention. Changes therein and other uses will occur to those skilled in the art

which are encompassed within the spirit of the invention as defined by the scope of the claims.

WHAT IS CLAIMED IS:

1. A non-natural transgenic mouse with a disruption in at least one allele of the corticotropin releasing factor receptor 2 (CRFR2) such that said mouse does not express corticotropin releasing factor receptor 2 protein from said allele.

2. The transgenic mouse of claim 1, wherein the DNA sequences for exons 10, 11, and 12 of said corticotropin releasing factor receptor 2 allele have been deleted.

3. The transgenic mouse of claim 2, wherein said DNA sequences have been replaced with a neomycin resistance gene cassette.

4. The transgenic mouse of claim 3, wherein said mouse is heterozygous for said replacement.

5. The transgenic mouse of claim 3, wherein said mouse is homozygous for said replacement.

6. The progeny of a mating between a mouse of claim 3 and a mouse of another strain.

7. A method of screening a compound for anxiety modulating activity, comprising the steps of:

a) administering said compound to the transgenic mouse of claim 5;

b) testing said mouse for anxiety-related behavior; and,

c) comparing anxiety-like behavior of said mouse with anxiety-like behavior in a second transgenic mouse of claim 5 to which said compound was not administered.

8. The method of claim 7, wherein said mice are tested for anxiety in an elevated plus maze.

9. A method of screening a compound for depression-modulating activity, comprising the steps of:

a). administering said compound to the transgenic mouse of claim 5;

b). testing said mouse for depression-like behavior; and,

c). comparing depression-like behavior of said mouse with depression-like behavior in a second transgenic mouse of claim 5 to which said compound was not administered.

10. A method of screening for compounds which control blood pressure, comprising the steps of:

a). administering a compound to the transgenic mouse of claim 5;

b). testing said transgenic mouse for alterations in blood pressure; and,

c). comparing alterations of blood pressure in said transgenic mouse with alterations of blood pressure in a second mouse, wherein said second mouse is selected from the group consisting of a transgenic mouse of claim 5 to which said compound was not administered and a wild type mouse to which said compound was also administered.

11. A method of screening for compounds which affect angiogenesis, comprising the steps of:

a). administering a compound to the transgenic mouse of claim 5;

b). assaying said transgenic mouse for alterations in angiogenesis; and,

c). comparing alterations of angiogenesis in said transgenic mouse with alterations of angiogenesis in mice selected from the group consisting of transgenic mice of claim 5 to which said compound was not administered and wild type mice to which said compound was administered.

12. A method of screening a compound for effects on the response of the hypothalamic-pituitary-adrenal axis to stress, comprising the steps of:

a). administering said compound to the transgenic mouse of claim 5;

b). placing said mouse in a stress-inducing situation,

c). monitoring plasma levels of corticosterone and adrenocorticotropic hormone in said mouse; and,

d). comparing said levels to those in a transgenic mouse of claim 5 not placed in said stress-inducing situation.

13. The method of claim 12, wherein said stress-inducing situation is physical restraint-stress.

14. A method of determining the effects of CRFR2 on a second protein, comprising the steps of

a). administering an agonist that affects the second protein to the transgenic mouse of claim 5;

b) performing an assay of the second protein, wherein said assay is selected from the group consisting of assays of protein expression and assays of protein activity; and,

c). comparing assay results on said transgenic mouse with those obtained from a wild type mouse administered the same agonist.

15. The method of claim 14, wherein said second protein is selected from the group consisting of corticotropin releasing factor, corticotropin releasing factor receptor 1, urocortin, corticotropin receptors and urocortin receptors.

16. A method of stimulating increased angiogenesis in a target tissue comprising the step of administering a CRFR2 antagonist to said target tissue.

17. The method of claim 16, wherein said CRFR2 antagonist is an antisense nucleotide directed against CRFR2.

18. The method of claim 16, wherein said target tissue is selected from the group consisting of heart, brain, pituitary, gonad, kidney, adipose, and gastrointestinal tract tissues.

19. The method of claim 16 wherein said angiogenesis is increased in an individual having a pathophysiological condition selected from the group consisting of infarction, stroke, and injury.

20. A method of inhibiting angiogenesis in a target tissue comprising the step of administering a CRFR2 agonist to said target tissue.

21. The method of claim 20 wherein said CRFR2 agonist is selected from the group consisting of urocortin and CRF.

22. The method of claim 20, wherein said tissue is selected from the group consisting of heart, brain, pituitary, gonad, kidney, adipose, and gastrointestinal tract tissues.

23. The method of claim 20 wherein said angiogenesis is inhibited in an individual having a pathophysiological condition selected from the group consisting of cancer and diabetic retinopathy.

24. A method of stimulating hair growth comprising the step:

contacting urocortin with a region of skin on which hair growth is desired.

25. The method of claim 24, wherein said urocortin is implanted under the skin.

26. The method of claim 24, wherein bFGF is administered to said skin before urocortin, after urocortin or simultaneously with urocortin.

27. The method of claim 24, wherein urocortin is contained in a composition with bFGF.

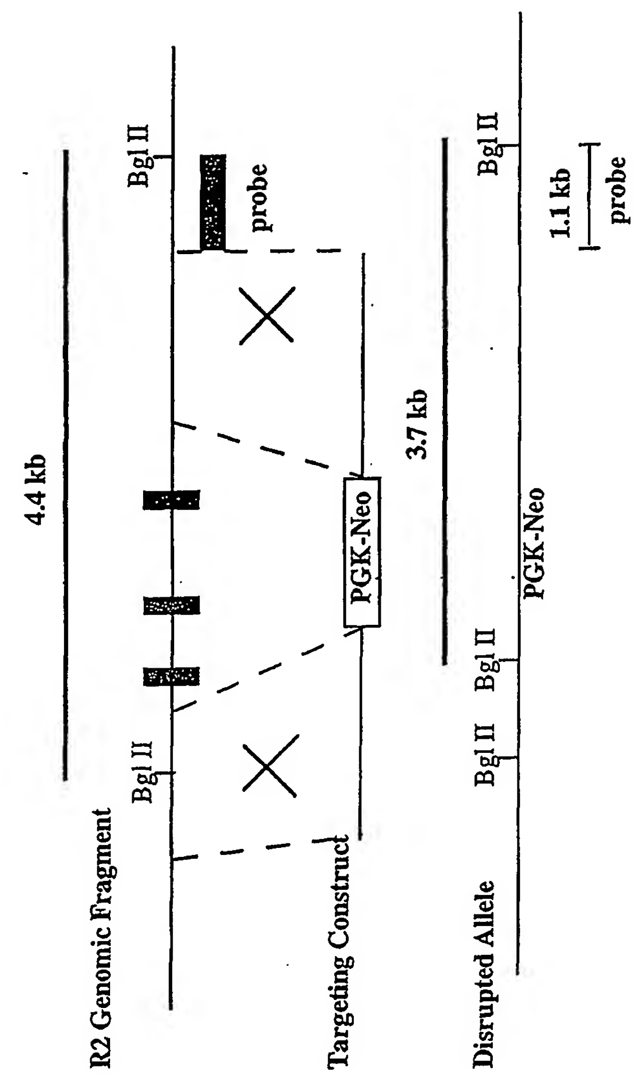

R2 Genomic Fragment
Targeting Construct
Disrupted Allele
4.4 kb
3.7 kb
1.1 kb
Bgl II
Bgl II
Bgl II
Bgl II
Bgl II
probe
probe
PGK-Neo
PGK-Neo

Fig. 1A

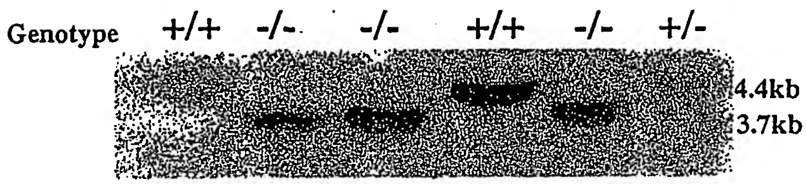


Fig. 1B

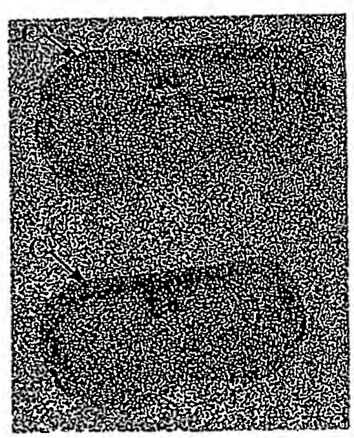


Fig. 1C

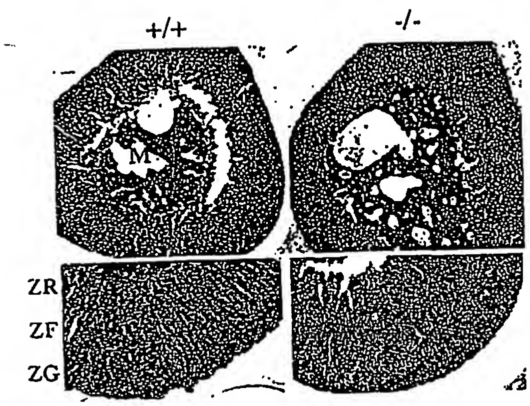


Fig. 1D

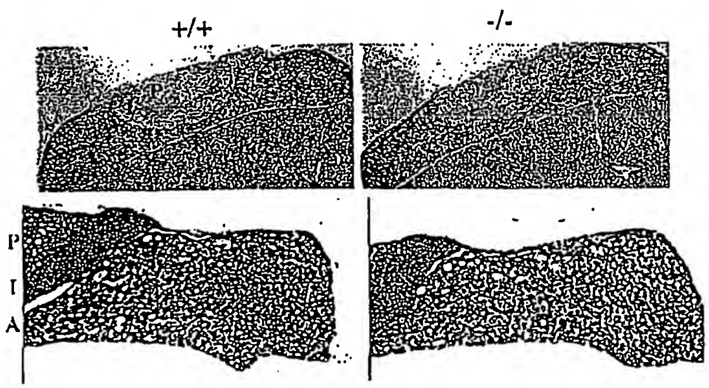
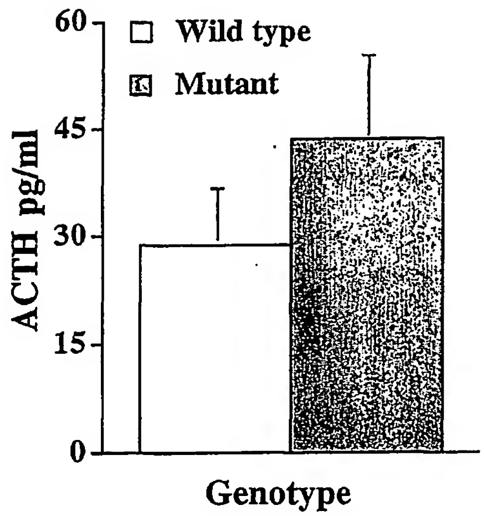
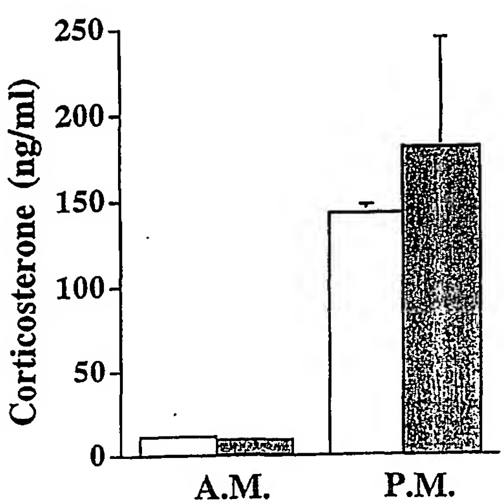


Fig. 1E



60
45
30
15
0
ACTH pg/ml
Wild type
Mutant
Genotype

Fig. 2A



250
200
150
100
50
0
Corticosterone (ng/ml)
A.M.
P.M.

Fig. 2B

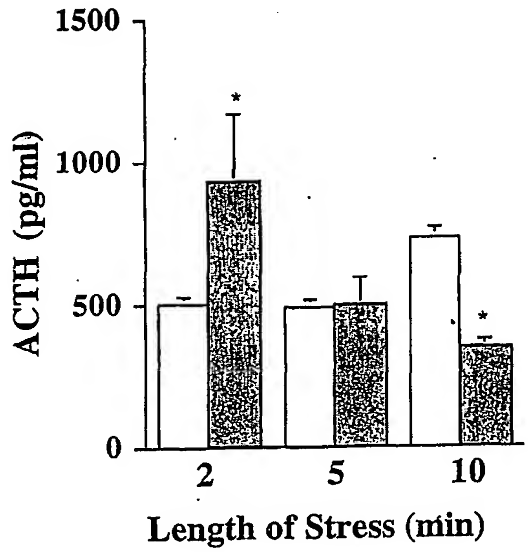

1500
1000
500
0
ACTH (pg/ml)
*
*
2
5
10
Length of Stress (min)

Fig. 2C

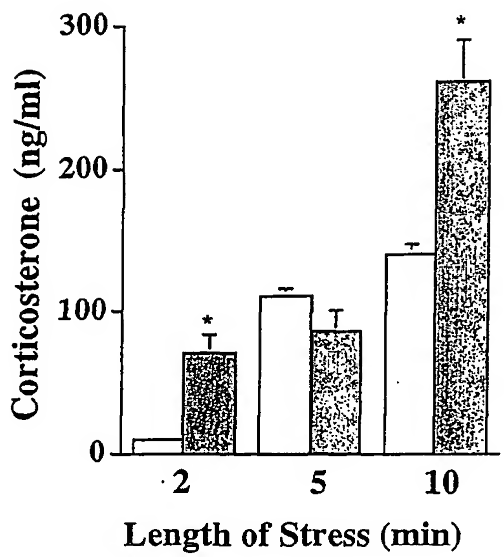

300
200
100
0
Corticosterone (ng/ml)
*
*
2
5
10
Length of Stress (min)

Fig. 2D

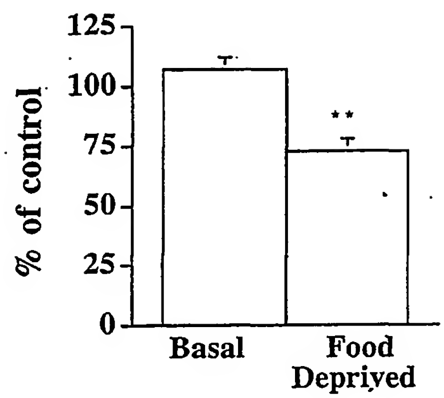

125
100
75
50
25
0
% of control
**
Basal
Food
Deprived

Fig. 3A

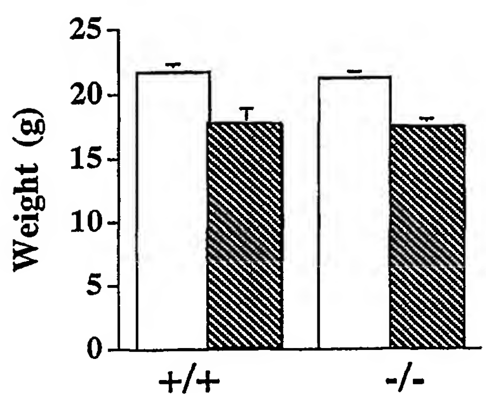

25
20
15
10
5
0
Weight (g)
+/+
-/-

Fig. 3B

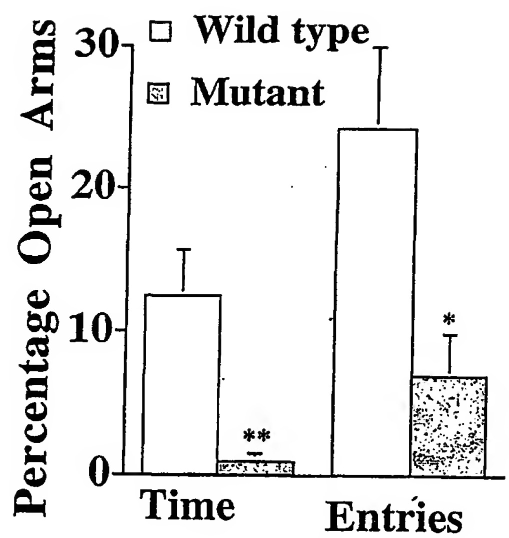

Wild type
Mutant
Percentage Open Arms
30
20
10
0
**
*
Time
Entries

Fig. 4A

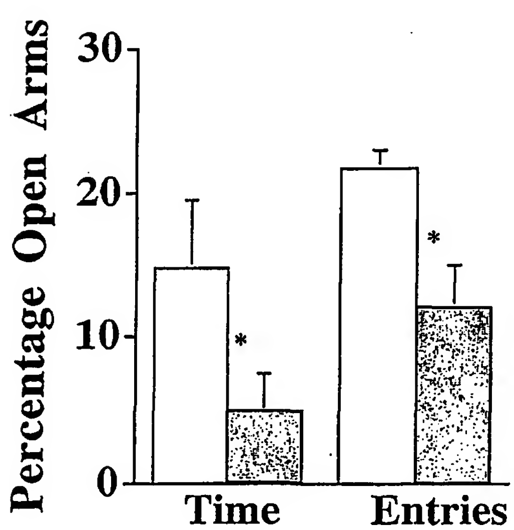

Percentage Open Arms
30
20
10
0
*
*
Time
Entries

Fig. 4B

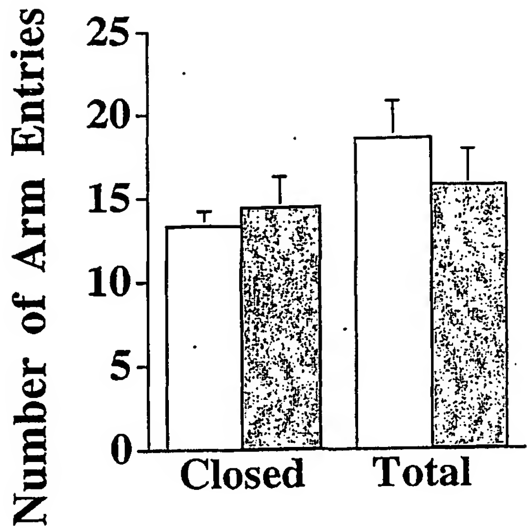

Number of Arm Entries
25
20
15
10
5
0
Closed
Total

Fig. 4C

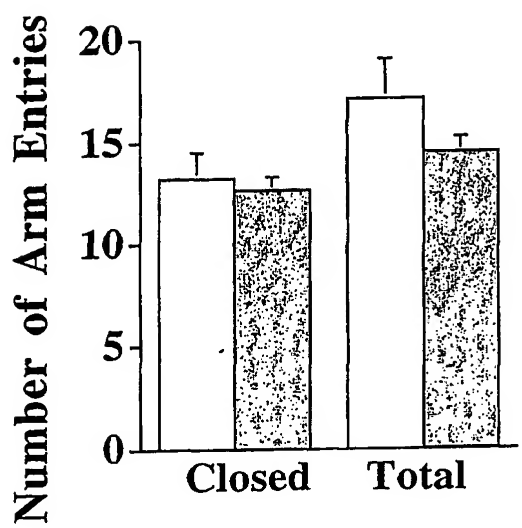

Number of Arm Entries
20
15
10
5
0
Closed
Total

Fig. 4D

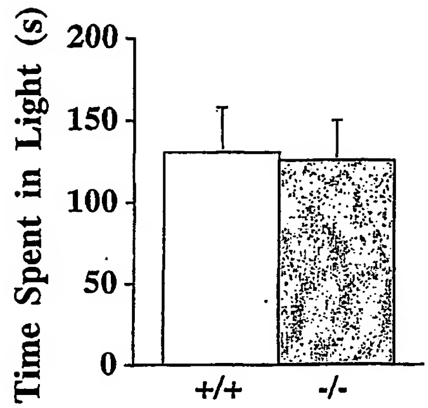

Time Spent in Light (s)
200
150
100
50
0
+/+
-/-

Fig. 4E

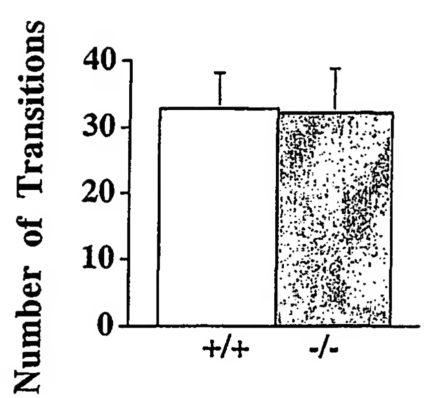

Number of Transitions
40
30
20
10
0
+/+
-/-

Fig. 4F

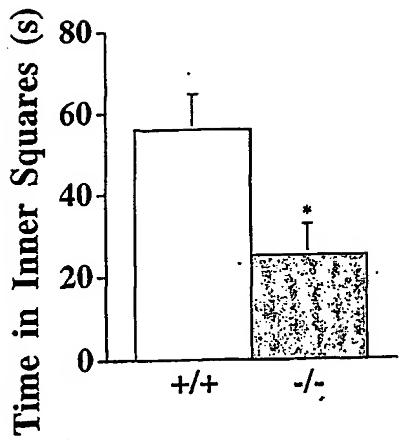

Time in Inner Squares (s)
80
60
40
20
0
*
+/+
-/-

Fig. 4G

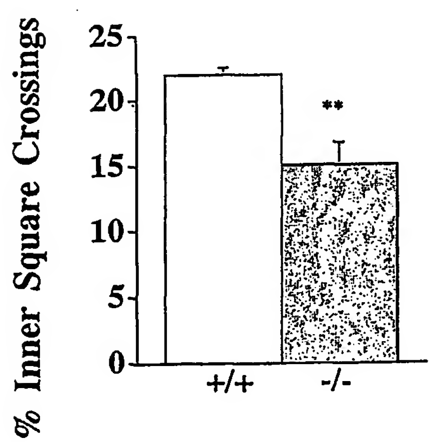

% Inner Square Crossings
25
20
15
10
5
0
**
+/+
-/-

Fig. 4H

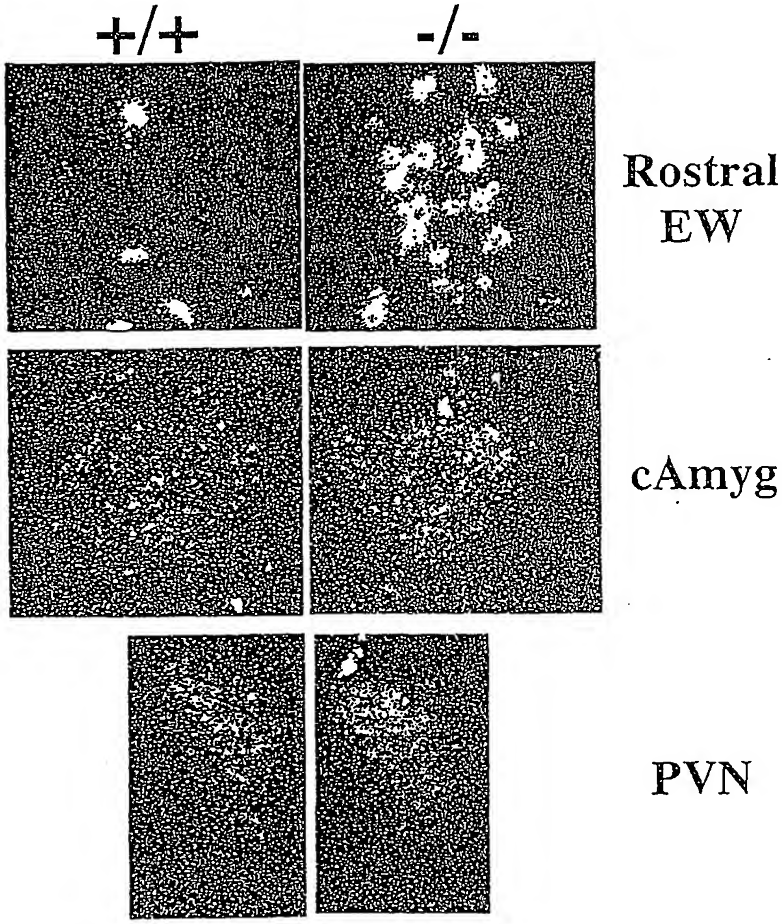


Fig. 5A

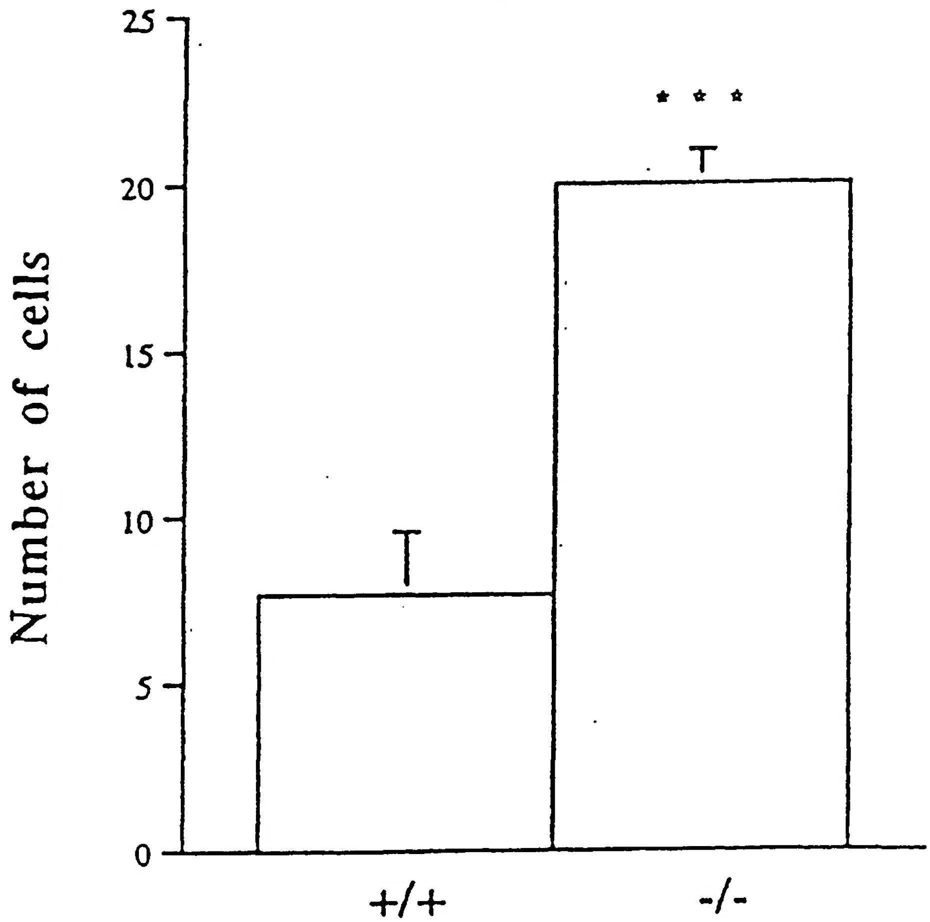


Fig. 5B

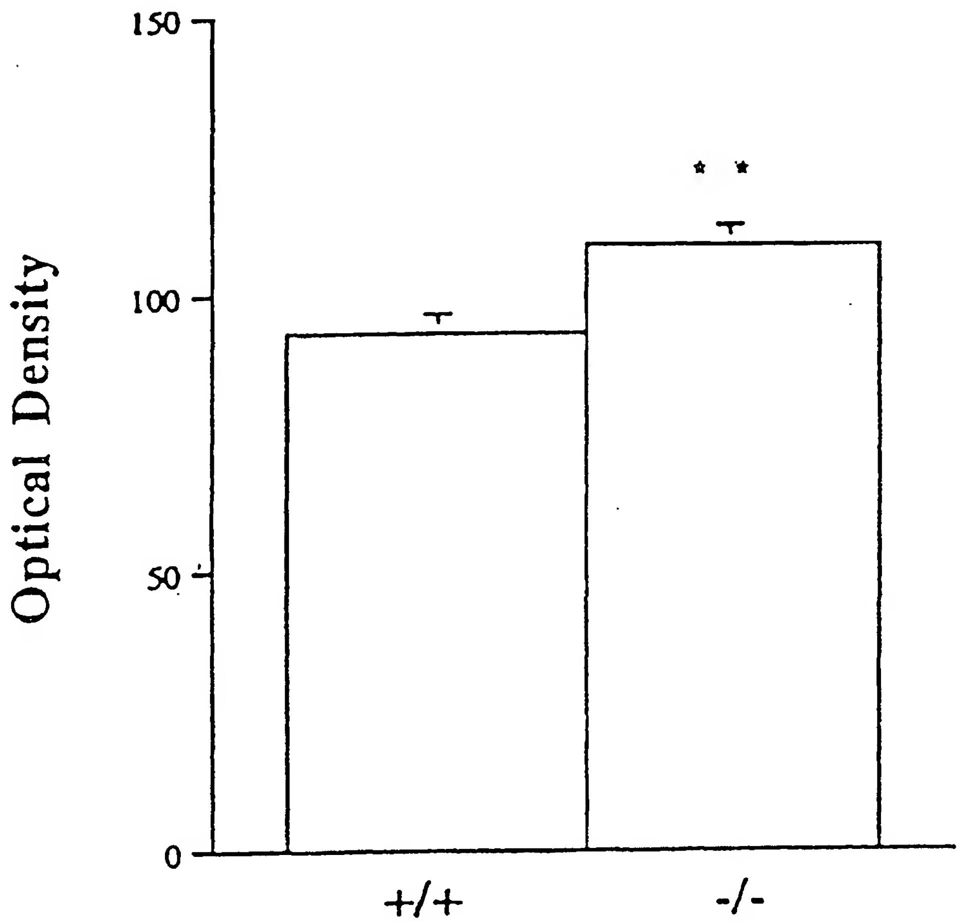


Fig. 5C

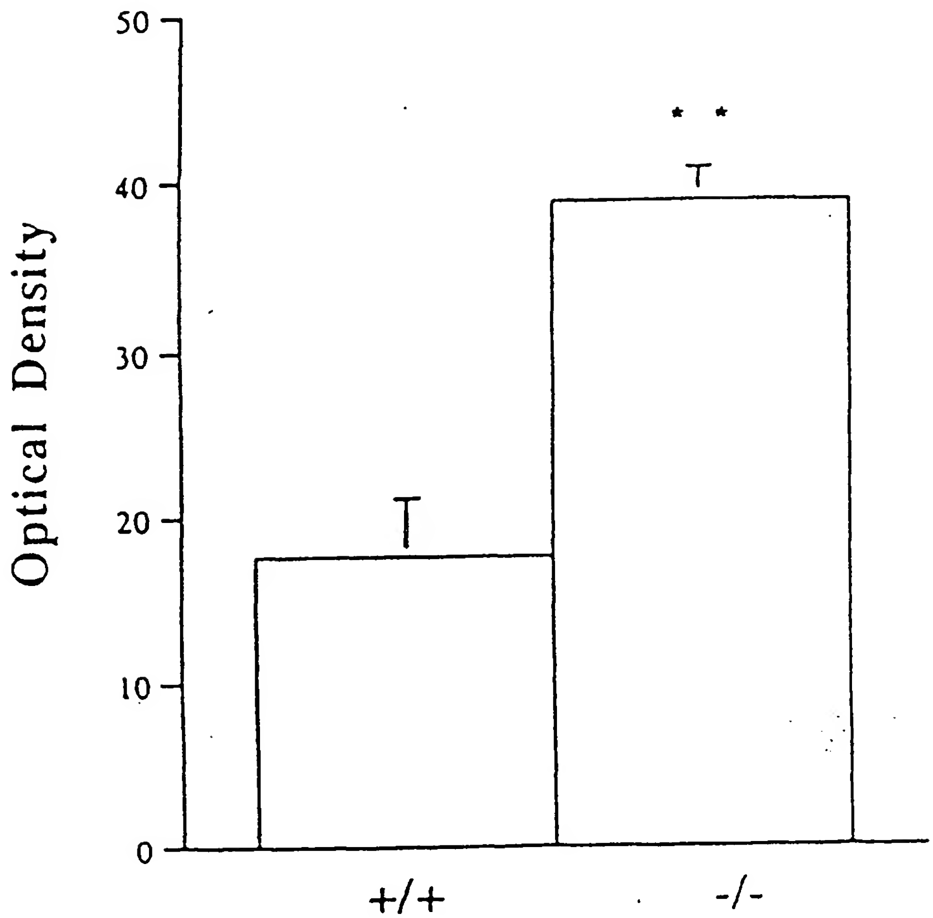


Fig. 5D

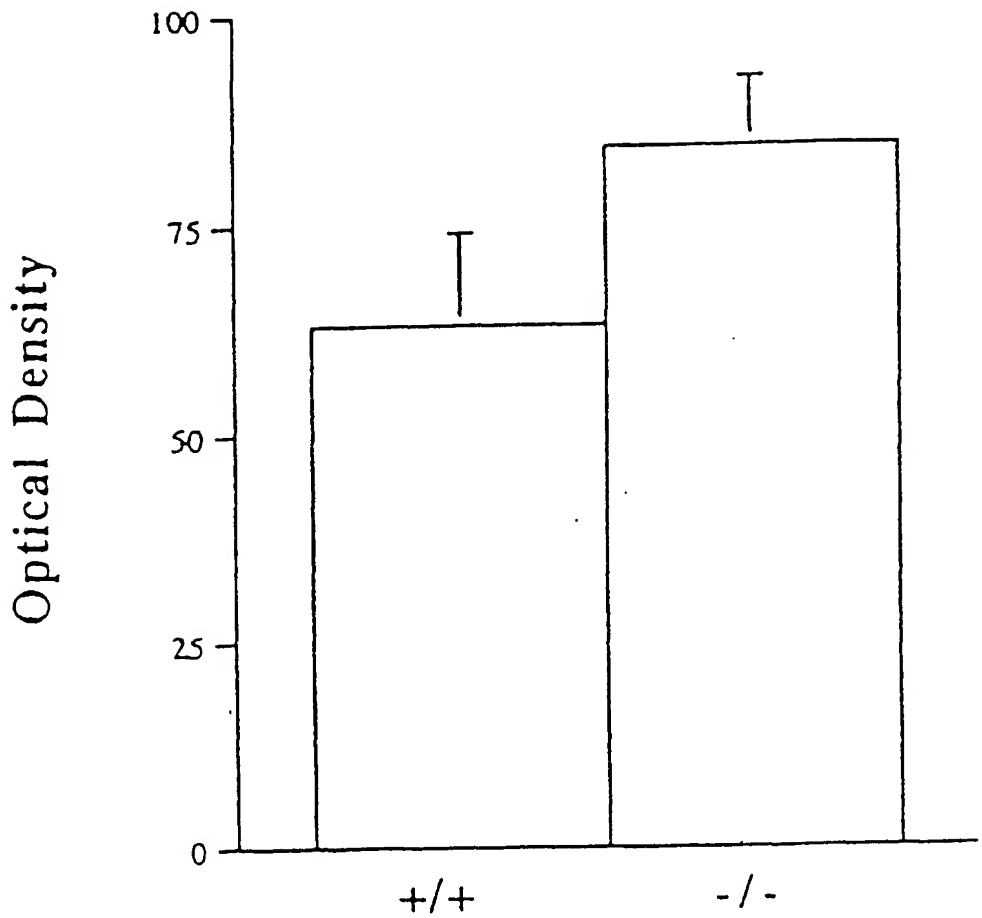


Fig. 5E

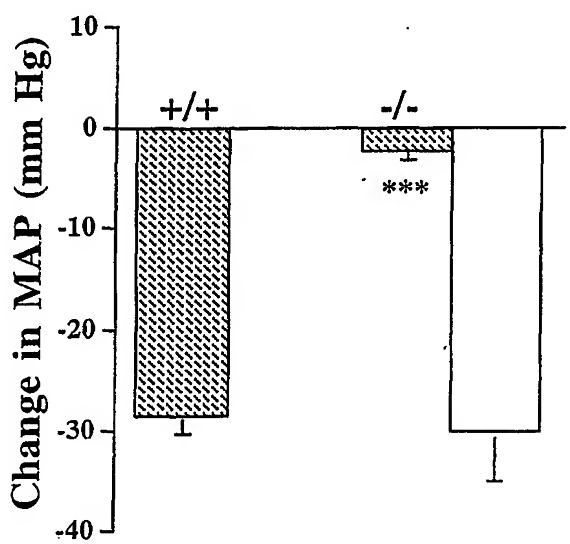


Fig. 6

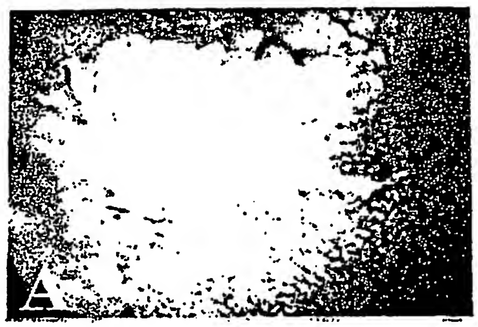


Fig. 7A

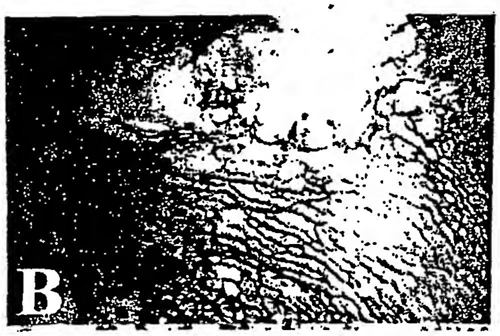


Fig. 7B

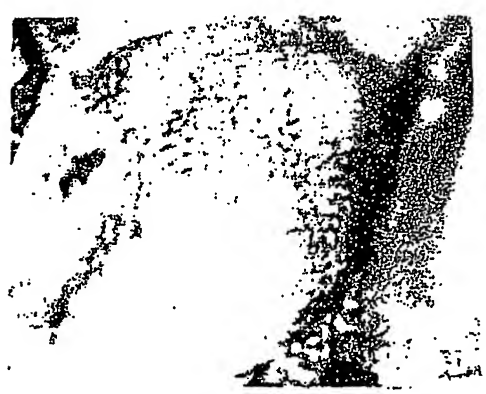


Fig. 7C

Fig. 7D

Fig. 7E

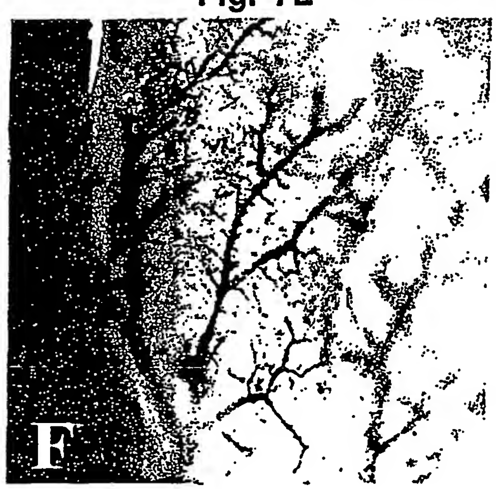


Fig. 7F

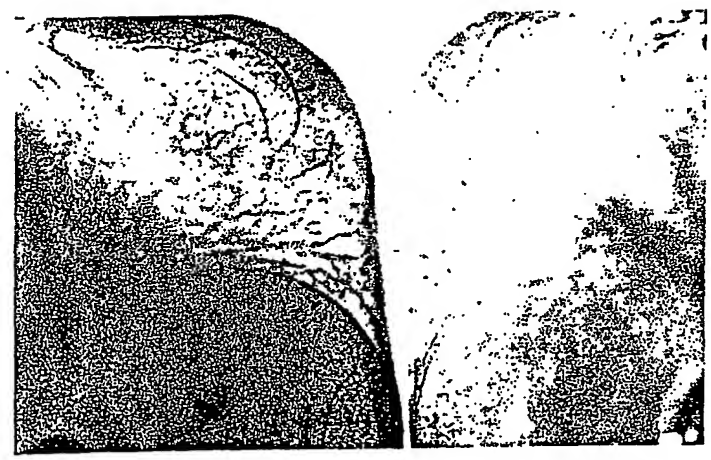


Fig. 8A

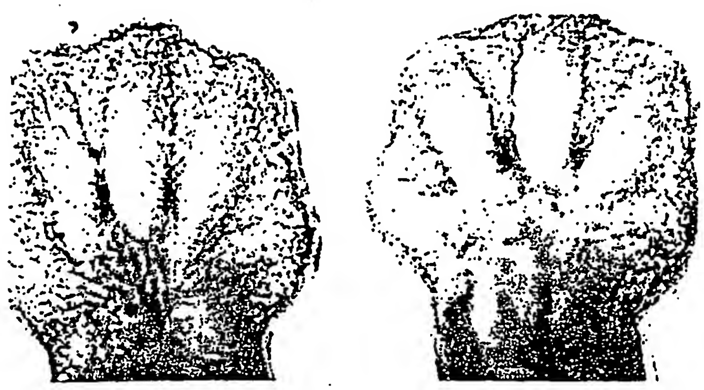


Fig. 8B

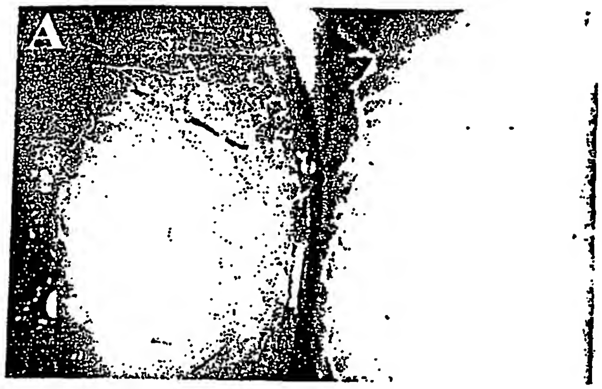


Fig. 9A

Fig. 9B

Fig. 9C

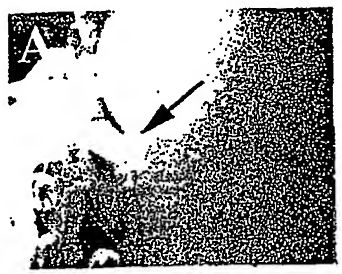


Fig. 10A

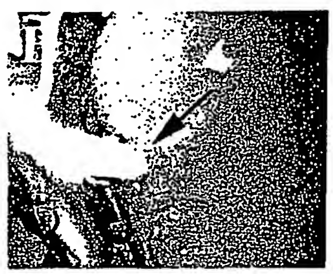


Fig. 10B

Fig. 10C

Fig. 10D

Fig. 10E

Fig. 10F

Fig. 11A

Fig. 11B

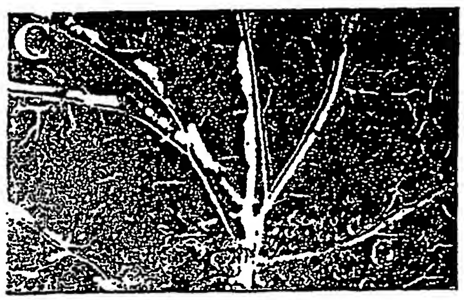


Fig. 11C

Fig. 11D

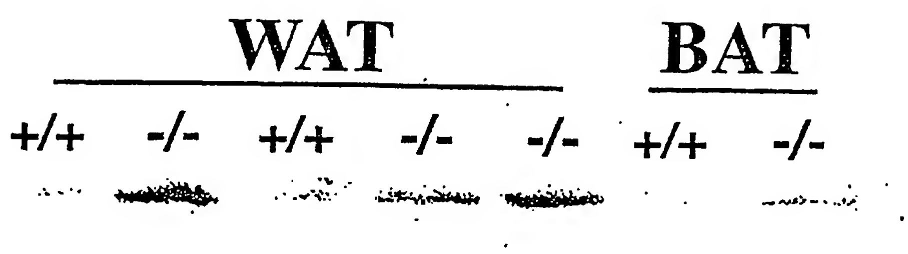


Fig. 12

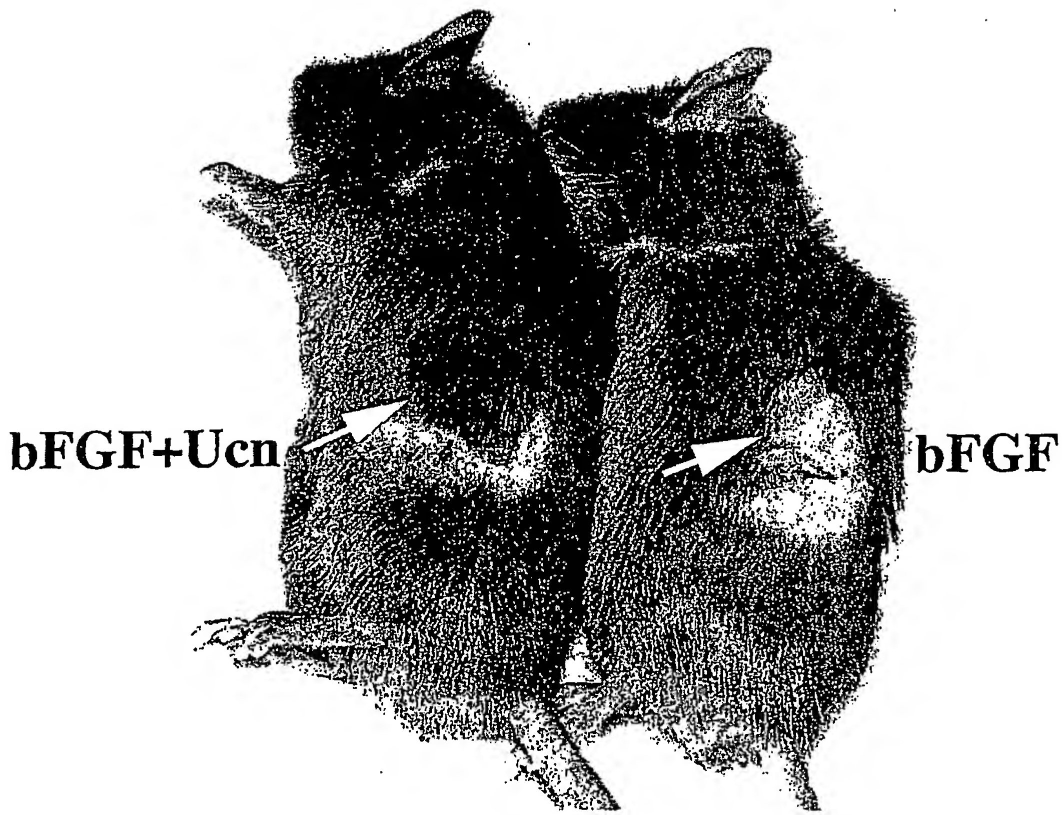


Fig. 13